Cadernos do Laboratorio Xeolóxico de Laxe
(2023) Vol. 45, pags. 1–16
Instituto Universitario de Xeoloxía
Universidade da Coruña

ISSN: 0213-4497
eISSN: 2173-6936

Characterization of joint mortars and pavements from the Roman site of A Ciadella (NW Spain)

Caracterización de morteros de junta y pavimentos del sitio romano de A Ciadella (NO de España)

Enrique M. ALONSO-VILLAR[1], Teresa RIVAS[1*], Adolfo FERNÁNDEZ[2], Marta LAGO[2], Alba RODRÍGUEZ[2], Patricia VALLE[2]

[1] CINTECX, Universidade de Vigo, Campus As Lagoas- Marcosende, 36310 Vigo, Spain.
[2] GEAAT, Facultade de Historia. Campus As Lagoas 32004 Ourense. Universidade de Vigo.

* Corresponding author: trivas@uvigo.gal

https://doi.org/10.17979/cadlaxe.2023.45.0.9385
received: 25/11/2022 acepted: 20/01/2023

Abstract

The results of the mineralogical and textural characterization of joint mortars and pavement samples collected at the Roman site of A Ciadella (Galicia, NW Spain) are presented. The results indicate that these are earth mortars whose most likely origin could be sub-surface horizons from nearby soils, considering the mineralogical similarity between the inherited minerals detected in the mortars and the mineralogy of the rocks in the area. No lime has been detected in any mortar. The textural analysis confirms a poor pre-treatment of the soil samples used as raw material. In the pavement samples analysed, the existence of a kaolinite-rich surface layer, probably applied deliberately on the surface, stands out.

Keywords: Roman site of A Ciadella, joint mortar, lime mortar, earth mortar, pavement

Resumen

Se presentan los resultados de la caracterización mineralógica y textural de morteros de juntas y muestras de pavimentos recogidas en el yacimiento romano de A Ciadella (Galicia, NW Spain). Los resultados indican que se trata de morteros de tierra cuyo origen más probable podrían ser horizontes subsuperficiales de suelos cercanos, considerando la similitud mineralógica entre los minerales heredados detectados en los morteros y la mineralogía de las rocas de la zona. No se ha detectado cal en ningún mortero. El análisis textural confirma un pretratamiento muy básico de las muestras de suelo utilizadas como materia prima. En las muestras de pavimento analizadas destaca la existencia de una capa superficial rica en caolinita, probablemente aplicada de forma deliberada sobre la superficie.

Palabras clave: yacimiento romano de A Ciadella, morteros de junta, morteros de cal, morteros de tierra, pavimento

1. INTRODUCTION

One interesting information that emerges from the study of the composition of the construction materials of archaeological cultural heritage is the identification of supply sources of raw materials; this information allows establishing communication and commercial routes as well as deducing the degree of the technological development of societies. The Roman fortress of A Ciadella represents an exceptional example to approach the analysis of the materials used in the construction of walls and pavements with the aim of expanding knowledge on the degree of transfer of technology between the local and the foreign populations in the provinces under the rule of the Roman Empire.

The archaeological site of A Ciadella presents a long occupation. The first phase corresponds to the construction of the Roman fortress, most probably in the Flavian period. Later, at the beginning of the 2nd century, it was occupied by the *Cohors prima Celtiberorum*, which remained there until the end of the 3rd century. During these years, the military buildings underwent various renovations and other buildings were built with various functions, such as a large *horreum* east of the *Principia*. Once abandoned by the Roman army, the buildings were used for civilian uses, perhaps as a small late Antique village. Already in the early medieval period, a church was built with a large associated necropolis. The site was probably abandoned in the 12th or 13th century when the church was moved outside the fortress. Until the present day, the area occupied by the camp has been used for agricultural purposes.

From a constructive point of view, the building stones used in the walls of the Roman fortress of A Ciadella are varied, reflecting the geological diversity of the area. So, fragments of different metamorphic rocks with clear schistosity are distinguished: *Ollo de Sapo* gneiss, that outcrops in the surroundings, granulite-type metabasic rocks, metamorphic rocks of amphibolite composition and, occasionally, fragments of serpentinized peridotite. Visual analysis of the walls confirms the use of mortars to join the rock fragments together.

The composition and technology of mortars as construction material is well known (ELSEN, 2006). Mortars are made by mixing an aggregate with a material that acts as a binder between the aggregate grains to obtain a more or less homogeneous consistency paste that is easy to apply. Once applied on site, the paste hardens, either simply by loss of moisture (drying) or by the development of some chemical reaction. Historically, lime (aerial and hydraulic), gypsum and clay (earth mortars) were used as binders, materials whose use has been gradually reduced due to the appearance of *Portland* cement. Clay-based mortars (earth mortars) are the oldest, described in the 8th millennium BC in Mesopotamia and Babylon (WRIGHT 2005; PACHTA et al., 2014). Around the 2nd millennium BC, lime begins to be used, either alone or mixed with clay, ash or straw (DAVEY, 1961; PALIVOU, 1999) or, in the case of mortars with a structural function, with pozzolanic additives (CONOPHAGOS et al., 1974).

In the Iberian Peninsula, there is evidence of the addition of lime to mortars since the Iron Age (SÁNCHEZ GARCÍA 1999; PASTOR QUILES, 2017), although in areas where supplies were ensured by the proximity of geological sources of calcium carbonate (limestones, marbles…) or hydraulic limes. In those geographical areas where the sources of these raw materials are limited, joint mortars used in the *oppidum* were made with earth (clay and sand; SILVA HERMO et al., 2008), with saprolite (DE LA PEÑA, 1992) or by adding kaolinite-rich clays (GÓMEZ et al. 2021). During the Roman Empire, the use of aerial lime and pozzolanic clays (hydraulic limes) became dominant in the field of construction once their advantages as a construction material were discovered. And so, since ancient times, the appropriate methodology of manufacture and application was defined regarding the type of binder, the grain size distribution of the aggregate and the aggregate:cement ratio (27-23 BC, VITRUVIUs et al., 1960). Thus, the scarce existing literature regarding the composition of mortars in Roman-age sites on the peninsula (ALONSO-OLAZABAL et al., 2020; ERGENÇ, 2017; ONTIVEROS-ORTEGA *et al.*, 2016) highlights the predominance of lime (aerial and hydraulic) as a binder in *opus caementitium* and *opus signinium*; only in some cases was the presence of earth detected as an additive to confer dark colors. Work carried out recently at the archaeological site of Cibdá de Armea (Ourense, Spain; internal report) confirms, on the contrary, the absence of lime in the mortars for joints and pavements and the use, instead, of moderately pre-treated earth to remove coarse fractions.

In this work, we present the results of the characterization of the joint mortars of some walls of the Roman fortress of A Ciadella; the study aims to 1) increase knowledge about the materials and technology applied in the construction of the walls, 2) provide information about possible supply areas of aggregate and binder and about the technological development related to the selection and pre-treatment of the raw materials and to the mortar manufacturing and 3) confirm the similarity between the materials and technology applied in this site compared to others of the same age (Cibdá de Armea) or somewhat older in Galicia (GÓMEZ et al., 2021).

2. MATERIAL AND METHODS

2.1. Samples collected

During the excavation campaign carried out in July 2020, samples of 6 joint mortars and one pavement (the only pavement found in the site) were collected in different places of the Roman fortress of A Ciadella, under the supervision of the team of professional archaeologists and conservators who at that time were working on site. The mortar samples were collected from the walls and other most relevant construction structures in order to relate them to the different construction phases of the fort.

Figure 1 depicts the map of the archaeological site with the location of the samples; Figures 2 and 2 (cont.) include images of the collected samples and their location.

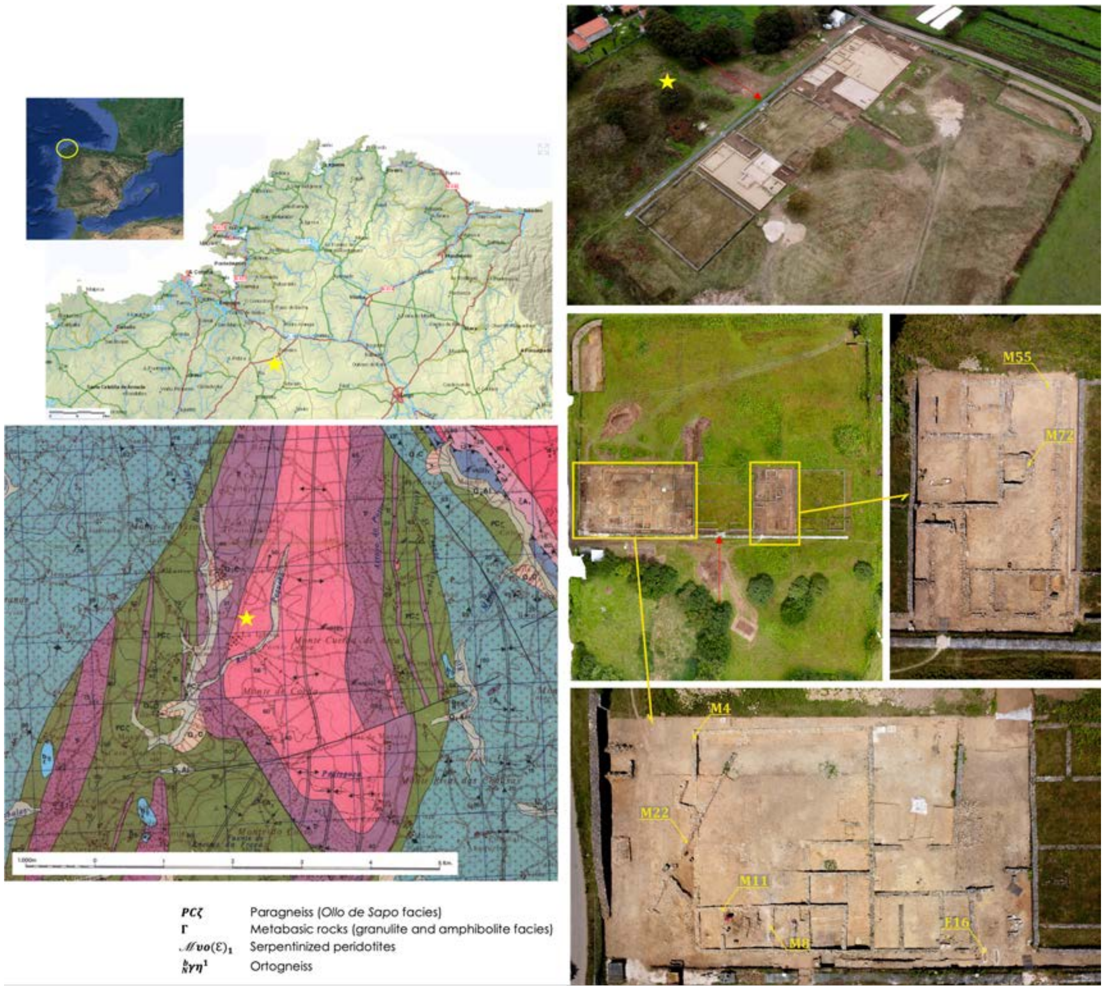

Figure 1: Location of A Ciadella Roman fortress (marked with a yellow asterisk) in NW Spain and images of the location of the samples in the different walls of the archaeologic site. Information is also included on the geological substrate of the area (from IGME 1980); the site is located right on the border between *serpentinized peridotites* and *metabasic rocks* formations.

The list of joint mortar samples, with indications of their color (MUNSELL, 1994) and of the shape of the aggregates and the degree of development of the structure (using descriptive for edaphic horizons) is as follows:

- M11: granular structure of medium development degree; color 10 YR 6/4.
- M8: prismatic structure of medium development degree; color 2.5Y 7/4.
- M22: granular structure of medium development degree; color 10 YR 5/4.
- M4: granular structure of weak degree of development; color 2.5Y 6/4.
- M72: granular to subangular structure and medium degree of development; abundant roots and other plant remains. Color 2.5Y 5/4.
- M55: granular structure and weak degree of development; color 10 YR 5/6
- E16: earth pavement with granular structure and weak degree of development; color 10 YR 7/3. Its general color is brownish-yellowish but a local whitish coloration (10YR 8/2) is observed affecting an area of 100 cm × 45 cm and only up to 2 cm deep from the surface (Fig. 1 cont.); in some points, the limit between the whitish zone and the earthy material is diffuse; in others, however, the limit is net. A sample

of the earthy material (E16) and the material affected by the whitish coloration (E16b) was collected in this pavement.

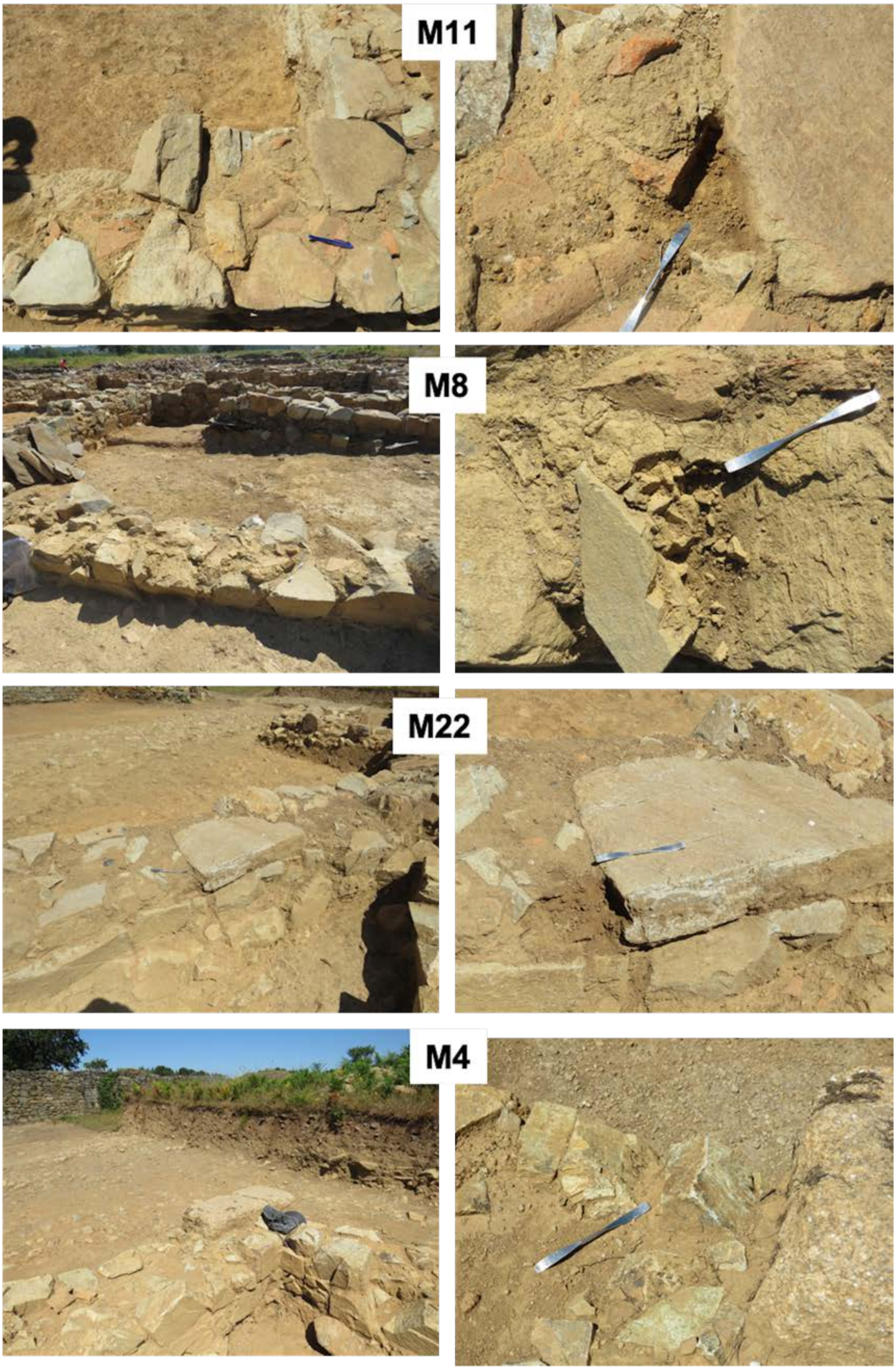

Figure 2: Location and detail of joint mortar samples M11, M8, M22 and M4. The tip of the spatula identifies the sampling point.

Figure 2b (cont.): Location and detail of mortar samples of joints M72 and M55 and pavement E16. The tip of the spatula identifies the sampling point. A detail of the surface of pavement E16 is also shown, which makes it possible to distinguish the more whitish color that affects the most superficial 2 cm (where sample E16b was collected) in contrast to the rest of the pavement, which has a more reddish color.

2.2. Methods of analysis

All mortar and E16 and E16b pavement samples were analysed by applying the following methods:

- Elemental analysis using a LECO CNS2000 elemental microanalyzer that allows obtaining the total carbon and nitrogen content, as well as the determination of the inorganic carbon content through the generation of CO_2 by acid attack.

- Mineralogical analysis by X-ray diffraction, using a SIEMENS D5000 equipment and analysing the samples (ground to a grain size of less than 50 µm) using the random powder method. With these results, an estimate (semi-quantification) was made using the intensities of the maximum intensity diffraction peaks of each mineral and the reflective power of each mineral phase (obtained experimentally from artificial mixtures of commercial standards). The samples were also analysed by means oriented aggregate method, before and after calcination at 550 ºC, for the correct identification of minerals from the phyllosilicate group such as kaolinite, chlorite and vermiculite.

- Textural analysis. For this determination, a known weight of the sample (minimum 10 g), obtained by quartering, is put in contact with 200 mL of distilled water and 10 mL of sodium hexametaphosphate (Na_2CO_3) and stirred for 2 hours. After this time, the sample was transferred to a battery of sieves with meshes of 2 mm, 1 mm, 0.5 mm, 0.25 mm and 0.05 mm to carry out a wet sieving. The fractions retained in each sieve were dried at 40 ºC and weighed. The sum of the fractions retained in the sieves constitutes, according to the USDA textural classification, the gravel and sand fraction (G+S), while the smaller fraction of 0.05 mm (estimated by weight difference) constitutes the silt+clay fraction (Si+C). In soil mortars, the G+S fraction could be considered the *aggregate fraction* and the Si+C fraction (together with carbonates and organic matter if there were any) could be considered the *agglomerant* and or *cementing fraction*. Within the aggregate fraction, there are gravels (fraction > 2 mm), very coarse sand (2-1 mm), coarse sand (1-0.5 mm), medium sand (0.5-0.25 mm) and fine and very fine sand thin (0.25-0.05 mm). Given the low content of organic matter in the samples, pre-treatment with oxygenated water was not carried out.

- Sample E16b was prepared as a cross section polished specimen and studied by optic microscopy (OM), using a ZEISS Axioscope 5/7KMAT, and by Scanning Electron Microscopy (SEM), using a FEI QUANTA 200 equipment with coupled energy-dispersive X-ray spectroscopy (EDS). For SEM visualization, the specimen was C- coated and observed using secondary (SE) and backscattered electron (BSE) detectors applying 20 kV and a working distance of 10 mm.

3. RESULTS

Table 1 shows the results of the analysis of the content of total and inorganic C and of total N. The S content is less than 0.3% in all the samples.

First of all, the non-carbonated nature of all the mortars and the pavement sample is confirmed: the inorganic carbon content is, in all cases, very low. Given its consistency and color, it would therefore be earth mortars.

Table 1: Content (%) of total nitrogen, total carbon, inorganic carbon and organic carbon of the analysed samples, including the pavement sub-sample E16b. The percentage of organic C over the total C of the sample is indicated in parentheses

Sample	Color	Structure/grade	Total N	Total C	Inorganic C	Organic C
M11	10YR 6/4	Granular/Medium	0.08	0.77	0.07	0.70 (91%)
M8	2.5Y 7/4	Prismatic/medium	0.04	0.38	0.04	0.34 (90%)
M22	10YR 5/4	Granular/Medium	0.27	2.67	0.21	2.46 (92%)
M4	2.5Y 6/4	Granular/weak	0.10	1.27	0.08	1.18 (93%)
E16	10YR 7/3	Granular/weak	0.08	0.93	0.08	0.85 (91%)
E16b	10YR 8/2	-	0.07	0.70	0.05	0.65 (92%)
M72	2.5Y 5/4	Granular/Medium	0.14	1.40	0.11	1.28 (93%)
M55	10YR 5/6	Granular/weak	0.04	0.44	0.09	0.35 (81%)

Taking into account the total carbon content, all the samples, except M22 and M72, would correspond to intermediate levels between ochric-type superficial horizons (carbon % less than 1%) and cambic-type sub-surface horizons. Mortar M22 would satisfy the organic C content condition of a typical mollic horizon (it is also the sample containing the highest % of N), although it must be considered that, to correctly classify these samples from the edaphic point of view, further analysis would be required of the organic fraction.

The sample with the highest total C content is M22 and the one with the lowest total C is M11 and E16b (the whitish colored sub-sample of pavement sample). In general, the total carbon content is directly related to a lower *value* (darker colors), with the exception of sample M55. No relationship was found between the degree of development of the structure and the content of organic and inorganic C; it must be taken into account that these are samples that, in some way, have been subjected to some minimal treatment; thus, the disturbance associated with kneading would undoubtedly modify the natural structure of the soil sample.

In Table 2, the mineralogic composition (% of the crystalline inorganic fraction) of the mortars and the pavement (including the whitish colored sub-sample of the pavement, E16b) is presented. In all the samples analysed, inherited primary minerals (present in the parent rock) and also secondary minerals, originating from the weathering of the primary ones, are detected. Calcium carbonate or hydraulic-type cementing phases are not identified in any sample.

In all the samples, quartz, micas (biotite and muscovite) and feldspars are detected, which would correspond to the inherited minerals. Regarding feldspars, potassium feldspar is detected in all samples except M22, and plagioclase in all samples, except M4 and M55; the identified plagioclase is albite, although anorthite is also detected in sample M22. Other inherited minerals detected are edenite (mineral of the amphibole group) -in M11, M22, M4 and E16 samples-, talc -in M4-, antigorite (mineral of the talc group) -in M72- and clinochrysotile -in M8 and M11-.

Table 2: Mineralogical composition (semiquantitative, in % of crystalline phases) of the mortar and pavement samples (E16 and E16b) obtained by x-ray diffraction. Cl: chlorite; V: vermiculite; M: mica; K: kaolinite; Q: quartz; KF: potassium feldspar; P: plagioclase; E: edenite; T: talc; CCR: clinochrysotile. tr: content lesser than 1%.

sample	color	CL	V	M	K	Q	KF	P	E	T	CCR
M11	10YR 6/4		45	2	22	27	1	4	tr		tr
M8	2.5Y 7/4		40	2	23	30	2	3			tr
M22	10YR 5/4	tr	20	2	25	36		16	tr		
M4	2.5Y 6/4	tr	33	3	19	27	13		tr	5	
E16	10YR 7/3	tr	16	15	26	30	9	4	tr		
E16b	10YR 8/2	5		11	25	39	19	2			
M72	2.5Y 5/4		17	4	12	28	2	6		31	
M55	10YR 5/6		35	3	35	23	4				

As secondary minerals, vermiculite and kaolinite are detected, in typical quantities of sub-surface horizons developed on similar rocks and climate (CALVO et al., 1987; VERDE, 2009). Vermiculite content exceeds kaolinite content in all samples except for the pavement sample, in which kaolinite is the main secondary mineral. The difference between the pavement (E16) sample and the whitish sub-sample (E16b) is the absence of vermiculite in the sub-sample; thus, the only secondary mineral of the clay fraction present in this subsample, kaolinite, would be responsible for the white color. No typical diffraction peaks of iron oxides are detected in any sample; so, Fe-rich mineral phases that would contribute (together with vermiculite) to the reddish-brown color of the samples would have low or no crystallinity.

The detected inherited minerals are as expected considering the geological substrate of the study area. According to IGME (1981), the site is located on the border of two important geological formations in the area, the *serpentinized peridotites* and the *metabasic rocks (granulite* facies and *amphibolite* facies) (Figure 1); both formations include rocks rich in amphibole, talc and clinochrysotile. In addition, outcrops of the gneiss *Ollo de Sapo*, which is composed of quartz, potassium feldspar, plagioclase, muscovite, biotite, zircon, apatite and tourmaline, are located nearby. In the inorganic horizons B, B-C and C type of the soils developed on these rocks, all these minerals would exist in varying amounts as inherited minerals. The presence of edenite, talc and clinochrysotile in all samples of mortars except for M55 would confirm that the raw material of these mortars comes from sub-surface horizons in the vicinity developed on the aforementioned rocks. The colors of the mortars, with *Hue* ranging between yellow (2.5Y) and brownish yellow (10YR), are also the typical colors of B, BC and C horizons developed on mafic under similar climates (VERDE, 2009).

Table 3 shows, for each mortar, the percentages of material corresponding to each granulometric fraction considered, as well as the percentages corresponding to the fraction smaller than 0.05 mm and larger than 0.05 mm. Three groups of samples are distinguished based on the texture:

1) The group of mortars M11, M8 and M4 are the ones that have the largest amount of material smaller than 0.05 mm (silt and clay fractions), always above 60%; in these samples, the ratio between the fraction of gravel plus sand (G+S) and silt plus clay (Si+C) is, consequently, lesser than 1. In these three mortars, the granulometric fraction greater than 0.05 mm with the most representation is that of sizes between 0.25 and 0.05 mm (fine and very fine sand). In these samples, texture is consistent with the mineralogy: they are the richest mortars in vermiculite (contents ranging 36-47%), a phyllosilicate present in soils in the clay fraction. This group of mortars would fit in terms of texture and mineralogy to B-type inorganic horizons developed on rocks similar to those of the geological substrate of this area under a similar climate.

2) The group of mortars M72 and M55 and the pavement E16 have percentages of silt and clay fraction less than 50%, especially the mortar M55 which, of all, has the coarsest texture (44% of the material is coarse sand, very coarse sand and gravel). The ratio G+S/ Si+C is, in all three cases, greater than 1. In the case of M72 and E16 samples, texture is also consistent with the mineralogy: the content of secondary minerals of phyllosilicate group in these mortars ranges from 31-21%, percentages significantly lower than those of the mortars with a silt-clay texture (M11, M8 and M4). Sample M55 has a very coarse texture, which is not consistent with its high content of secondary minerals (38%). The grain size distribution of this mortar is the worst graded of all the samples, which would indicate that, for its manufacture, the raw material was subjected to a grain classification to eliminate medium grained fractions.

3) M22 mortar has an intermediate texture between the two groups above. It should be noted that, although it has a % of Si+C fraction around 50%, it stands out for being the sample that has the highest % of gravel (particles larger than 2 mm in size). This fact is surprising because this mortar is, of all, the one with the highest organic C content, which would indicate a probable origin from an organic horizon. In this sense, the possibility of pre-treatment of the raw material for the manufacture of this mortar become more probable.

Table 3: For each sample, the % of material of each granulometric fraction (according to USDA textural classification), the % of material of grain size smaller than 0.05 mm (Si+C fraction, i.e. *cementing* fraction), the % of material of grain size greater that 0.05 mm (G+S fraction, i.e. *aggregate* fraction) and the ratio between G+S and Si+C fractions are indicated.

Size (mm)	**fraction**	**M11**	**M8**	**M22**	**M4**	**E16**	**M72**	**M55**
> 2	gravel	0.70	2.48	16.16	3.18	10.93	10.93	10.72
2-1	very coarse sand	1.85	1.32	6.14	1.92	7.73	7.73	18.91
1-0.5	coarse sand	5.18	2.15	8.37	3.92	6.87	6.87	16.44
0.5-0.25	medium sand	7.52	6.00	2.32	5.34	7.60	7.60	8.50
0.25-0.05	fine and very fine sand	24.43	23.03	13.92	22.07	17.38	17.38	19.27
<0.05	silt and clay	60.31	65.03	53.10	63.57	49.49	49.49	26.16
% >0.05 mm		39.69	34.97	46.90	36.43	50.51	50.51	73.84
%<0.05 mm		60.31	65.03	53.10	63.57	49.49	49.49	26.16
G+S/Si+C		0.66	0.54	0.88	0.57	1.15	1.02	2.82

It should be noted that in all cases, the morphology of the grains larger than 0.05 mm, that is, the fraction (G+S) is characterized by being hemispherical and with subangular edges. This morphology, together with the low degree of selection, conforms to that typical of the sand and gravel fraction of inorganic horizons of humid temperate climates on silicate rocks of the types that crop out in this area and that have been consulted in the bibliography (CALVO et al., 1987; VERDE, 2009). So, the hypothesis that the raw material to manufacture these mortars come from B-C horizons is confirmed by these features.

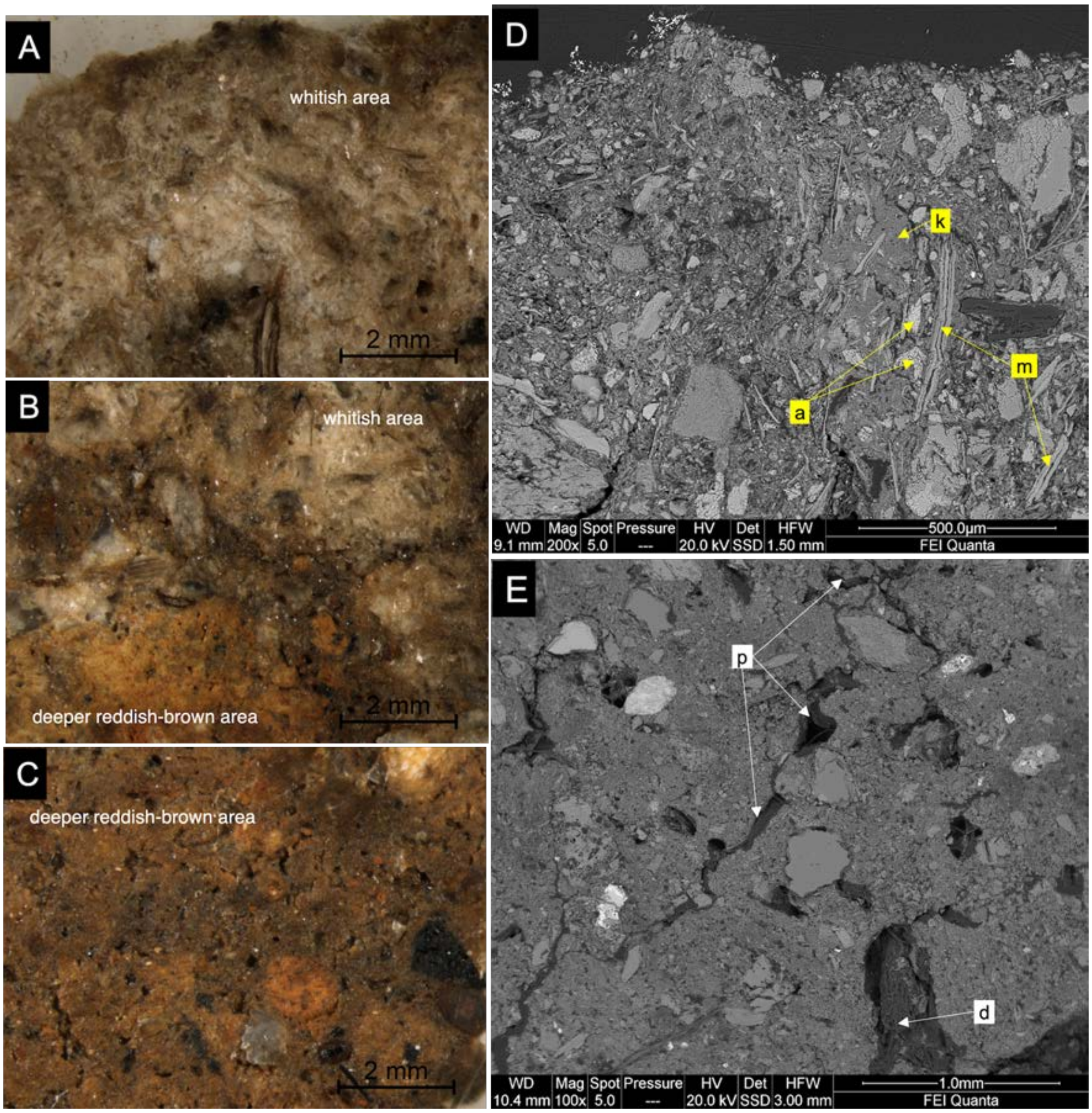

Figure 3: A, B and C are micrographs taken with optical microscope of the cross section of sample E16b, indicating the whitish coloration of the surface (A) which is lost from 2 cm towards the interior (B) giving way to the brow-reddish coloration (C). D and F are micrographs taken with SEM (BSE detector) in which fragments of silicate minerals (quartz, muscovite - marked with an m-, amphibole -a-) are embedded in a very fine-grained matrix of kaolinite (k); the black and dark grey areas are fissures, pores (p) and plant debris (d).

The observation of sample E16b under the optic microscope allows the whitish area (Figure 3A) to be clearly differentiated from the underlying mass of the pavement (Figure 3B and 3C), which is brownish-reddish in color; the boundary between both areas is diffuse (Figure 3B).

SEM analysis allows to verify that the pavement material (E16) and the whitish area (E16b) show a texture and a structure similar to that of an inorganic sub-surface horizon, occasionally distinguishing roots and other small plant remains (Figure 3E); the energy-dispersive x-ray microprobe confirm the presence of fragments of felsic silicates –in light grey in the BSE mode micrographs of Figure 2E- and mafic –bright under the same detector-; these fragments are embedded in a matrix of very fine grain size (less than 50 µm) rich in Si, Al and Fe, which would correspond to phyllosilicates aggregates (vermiculite and kaolinite, identified by x-ray diffraction) and forms of iron, which give the reddish brown colouration.

In the white area, the Fe content is low, as can be seen in the distribution maps of chemical elements in Figure 4; thus, in this area a lower content of Fe and a higher content of Si and Al are detected, elements that are present in an atomic ratio like that of kaolinite; these results would confirm that the whitish area of this sample is associated with an accumulation of kaolinite. The diffuse boundary between the kaolinite-rich area and the underlying brown soil material indicates that the kaolinite layer is likely due to a deliberate addition perhaps to obtain a smooth, grain-less surface more suitable for paving.

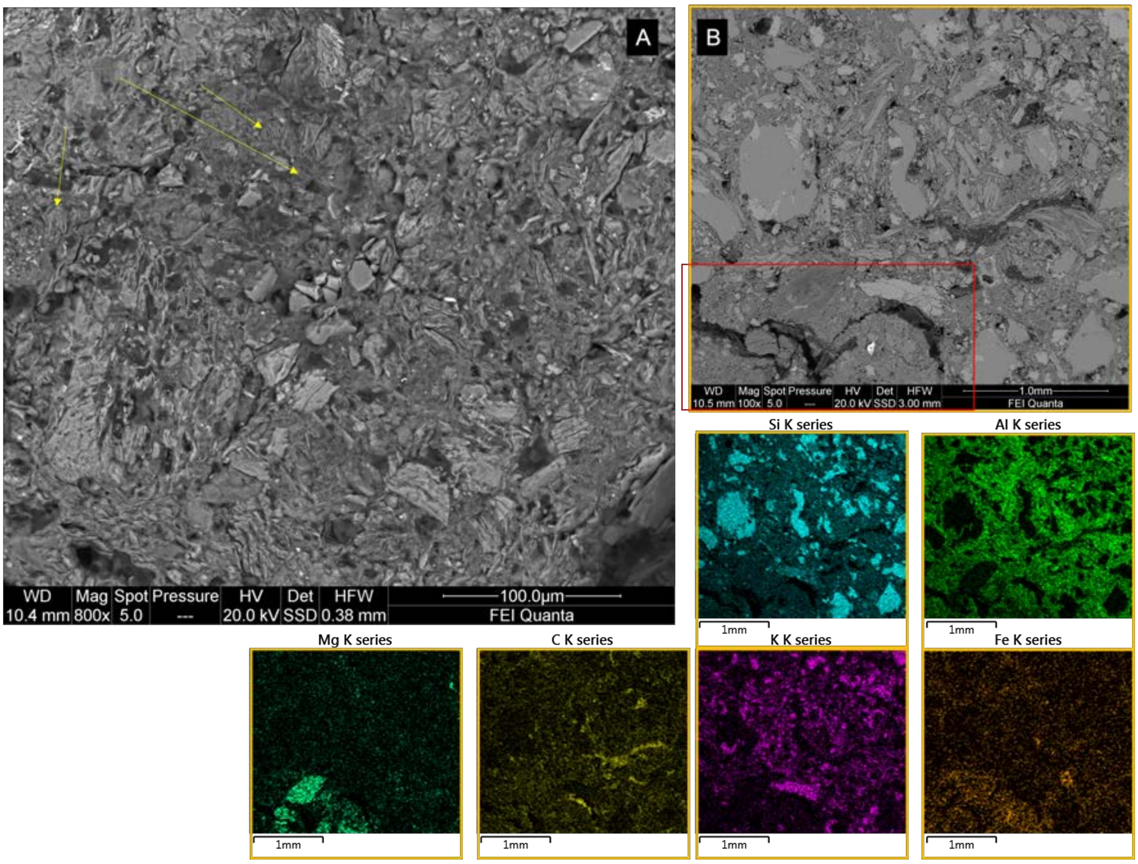

Figure 4 (previous page): A. Micrograph taken with SEM (BSE detector) of sample E16b, in an area of whitish coloring; the kaolinite packages are indicated with yellow arrows. B: micrograph taken with SEM (BSE detector) of sample E16b in the transition zone between the whitish area and the area not affected by the white color (lower left corner, indicated by a yellow box. The distribution maps of some chemical elements for the area pictured in B micrograph are attached: in the area not affected by the white color, Fe content is higher; carbon (C) marks the presence of organic remains, K marks the presence of feldspars and muscovite and Mg, together with Si, Al and Ca (not shown) indicate the presence amphibole particle.

4. CONCLUSIONS

The analysed mortars of this archaeological site are all earth mortars. Taking into account the texture and the presence of secondary minerals such as vermiculite and kaolinite, the raw material to prepare these mortars is likely to come from sub-surface soil horizons of B or BC-type (the most mortars) or A-type horizons (only one of them, the richest in organic carbon). The treatment that this raw material has undergone to manufacture the mortars, according to the results, seems to have been minimal; only a granulometric selection would be confirmed in two samples (M22 and M55) whose grain size distributions move away from the typical graded distribution of natural weathering systems. The results of the analysis of the only pavement sample analysed would confirm the possibility of a deliberate addition of kaolinite to the surface with the probable intention of obtaining a smooth surface.

The grouping of mortars regarding their texture provides a certain correlation with the different archaeological phases. Group 1(M4, M8 y M11), with a finer texture, comes from the wall mortars of Building 1 (Ed. 1), a probable troop barrack built in the first phase of the fort. The same mortars have been identified in the inner walls of the building, indicating that the compartments were contemporary to the outside walls of the structure. Group 2 (M72, M55 and pavement E16) with a coarser texture, comes from walls dated in later phases. However, it was identified in different phases. The M72 comes from the apse of the medieval church, while the M55 comes from the foundations of the big *horreum*, a building constructed during the lifespan of the fort in an empty area, located between the *Principia* and a troop barrack, and therefore still in the Roman period (end 2nd – beginning of the 3rd?). Lastly, pavement E16 was dated from the same period as the *horreum*. The last group, with a single mortar, corresponds to the phase that follows the abandonment of the fort, probably from the 5th century.

It is interesting to ascertain that only in one period there is a certain pre-treatment of the material, and it is related to the construction of the huge Roman fort. The mortars of this phase have a minimum treatment, something unexpected taking in mind that it is a military construction. However, we can confirm a more notable pre-treatment of the mortars during the remodelling phase (the construction of the *horreum* –M55) and the Late Roman occupation (M22).

The origin of the edaphic profiles that could supply the raw material to manufacture the mortars seems to be local, since in all the mortars, minerals present on the rocks that make up the geological substrate of the area were identify, particularly amphibole, talc and clinochrysotile present as main minerals in the metabasic (amphibolite facies) and serpentinized rocks which outcrops nearby.

These results confirm the preferential use of earthy materials (in this case, edaphic horizons) for the manufacture of joint mortars, reflecting the null relevance of lime in the manufacture of joint mortars in the construction field of Roman-age archaeological sites located in areas dominated by siliceous rocks. Taking into account other scientific works about construction materials from archaeological sites of similar ages or even older, the use of local raw material for the manufacture of mortars seems to be confirmed in A Ciadella site: the inexistence of sedimentary deposits relatively close to the archaeological site and the predominance of extensive weathering mantles in the area (highly determined by the mineralogical composition of the rocks) seem to have been determinant for the manufacture of the mortars of this archaeological site.

BIBLIOGRAPHY

Alonso-Olazabal, A., Ortega, L.A., Zuluaga, M.C., Ponce-Antón, G., Jiménez Echevarría, J., Alonso Fernández, C., 2020. Compositional Characterization and Chronology of Roman Mortars from the Archaeological Site of Arroyo De La Dehesa De Velasco (Burgo De Osma- Ciudad De Osma, Soria, Spain). *Minerals* 10 (5), 393. https://doi.org/10.3390/min10050393

Calvo, R., Macías, F., Buurman, P., 1987. Procesos de alteración y neoformación mineral en medios serpentiníticos de Galicia. *Cadernos do Laboratorio Xeolóxico de Laxe* 11, 161–174.

Conophagos, C., Badeca, H., 1974. The water cisterns of ore washers in Laurion and their special hydraulic mortar. *Hellenic Journal of Geosciences* 6, 328–337.

Davey, N., 1961. *A History of Building Materials*. London: Phoenix House.

De la Peña, A., 1992. *Castro de Torroso (Mos, Pontevedra). Síntesis de las Memorias de las Campañas de Excavaciones 1984-1990.* Arqueoloxía/Memorias 11. Xunta de Galicia, Consellería de Cultura e Xuventude, Dirección Xeral Do Patrimonio Histórico e Documental.

Elsen, J., 2006. Microscopy of historic mortars—a review. *Cement and Concrete Research* 36, 1416–1424. https://doi.org/10.1016/j.cemconres.2005.12.006

Ergenç, D., 2017. *Roman mortars used in the archaeological sites in spain and turkey: a comparative study and the design of repair mortars*. Doctoral thesis. Universidad Politécnica de Madrid. 07/09/2017.

Gómez Morgade, T., Rivas Brea, T., Carrera-Ramírez, F., Barbi Alonso, V., 2021. Earth mortars in the "Castro de Santa Trega" (A Guarda, Pontevedra, Spain). *Journal of Archaeological Science: Reports* 37, 102931. https://doi.org/10.1016/j.jasrep.2021.102931

IGME, 1981. *Mapa geológico de España, serie MAGNA. Hoja 71- Sobrado dos Monxes - E. 1:50.000.* Segunda serie, primera edición. Madrid: Servicio de publicaciones, Ministerio de Industria y energía.

Munsell, 1994. *Munsell soil color charts 1994 Edition*. New York: Munsell Publishing Company.

Ontiveros-Ortega, E., Rodríguez-Gutiérrez O., Navarro, A.D., 2016. Mineralogical and physical–chemical characterisation of Roman mortars used for monumental substructures on the Hill of San Antonio, in the Roman city of Italica (prov. Baetica, Santiponce, Seville, Spain). *Journal of Archaeological Science: Reports* 7, 205–223. https://doi.org/10.1016/j.jasrep.2016.03.043

Palivou, K., 1999. *Akrotiri of Thera: The Constructional Technology*. Athens: Library of the Archaeological Society at Athens.

Pachta, V., Stefanidou, M., Konopisi, S., Papayianni, I., 2014. Technological Evolution of Historic Structural Mortars. *Journal of Civil Engineering and Architecture* 8 (7) (Serial No. 80), 846–854. https://doi.org/10.17265/1934-7359/2014.07.005

Pastor Quiles, M. 2017. *La construcción con tierra en arqueología. Teoría, método, técnicas y aplicación.* Alicante: Publicaciones de la Universitat d'Alacant.

Sánchez García, A., 1999. Las técnicas constructivas con tierra en la arqueología prerromana del país valenciano. *Quaderns de prehistòria i arqueologia de Castelló* 20, 161–188.

S E R Vitruvius Pollio, Morgan, M.H., 1960. *Vitruvius: The Ten Books on Architecture*. New York: Dover Publications.

Silva Hermo, B., Prieto Lamas, B., Pereira Pardo, L., 2008. Análise dos factores de deterioración do castro de Viladonga. *CROA Boletin da Asociación de Amigos do Museo do Castro de Viladonga* 18, 14–19.

Verde Vilanova, J.R., 2009. *Influencia de los factores de formación y uso del suelo en las propiedades ándicas, formas y mecanismos de estabilización de carbono en suelos del noroeste de la península ibérica*. Doctoral thesis. Universidade de Santiago de Compostela, 2009.

Wright G.R.H., 2005. *Ancient Building Technology: Materials, Part 1: Text.* Leiden: Brill.